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# International materials institute for new functionality in glass (IMI-NFG) on-line learning library

Bill Heffner  
*Lehigh University*

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# The IMI On-line Glass Learning Library

William R. Heffner

Int. Materials Inst. for New Functionality In Glass  
Lehigh University, Bethlehem, PA

**A. Technical Lectures for the Professional**

**B. Outreach Activity for Students  
(Pre-College and College Students)**

**- Low-cost Learning Curriculum from the Kitchen Lab**



**<http://www.lehigh.edu/imi/>**

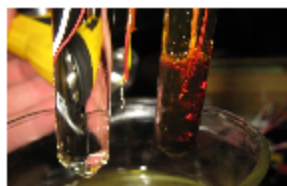


**International Materials Institute  
for New Functionality in Glass**

## On-line Glass Learning Library

An important goal of the IMI-NFG is to provide learning resources for the glass community. Here we present a large (and growing) collection of glass learning materials including on-line video lectures on a number of interesting and important glass topics, most by world leading glass experts. The categories include:

### Glass Education for Students, Teachers & General Public

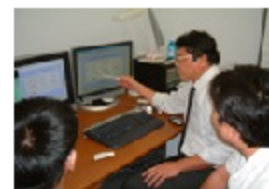


Glass-related information and activities to help the novice understand and appreciate the contribution and excitement of glass. Includes information, presentations, video clips, hands-on activities and ideas for exciting student projects for the home or school lab - all collected to compliment the glass learning experience. [More >](#)

### Technical Learning Library

More than 200 technical video lectures in glass

This section is aimed for the science and engineering students and professionals. For most of the material in this category, you will need to be logged in as a Member to view. Membership is free. [Log in or register here.](#)



The video lectures and material in the technical learning library include:

#### Semester Length Glass Courses

- Properties of Glass
- Characterization and Structure of Glasses
- US-Japan Winter School

#### Navigation Links

#### Learning Library:

Glass Education for Students, Teachers & General Public

Technical Learning Library

#### Quick Links:

Become a member

Plus many others – see actual page

## Technical Learning Library



Materials in this section are aimed at the science and engineering students and professionals. For most of the material in this listing, you will need to be logged in as a Member to view. There is no charge for membership, just an interest in glass science.

**Log in or register [here](#):**

The material in the technical learning library includes:

### A. Semester Length Glass Courses and Glass Schools (member log-in required to view)

#### [Optical and Photonic Glasses by Prof. Rui Almeida](#) -

There are 39 forty-five minute lectures delivered at Lehigh University in Spring 2005. To see the complete listing of all lectures, please click the link above. You can view a [Sample Lecture #1](#) without the member log-in.

[Characterization and Structure of Glasses](#) - A more advanced series of 26 ninety minute lectures by glass experts from six different universities. Course was delivered Spring 2007 semester.



[US Japan Winter School](#) - Thirteen international experts from Japan, US, Brazil and France lecture on application focused glass science topics. The lectures include 35 separate videos.

[Properties of Glass - New Item](#) - This series of 27 ninety minute lectures covers the properties of glass by glass experts from nine different universities. Course was delivered Fall 2008

### B. Tutorial & Advanced Topic Lectures (member log-in required to view)

#### [Tutorial and Advanced Lectures & Small Series](#)

Most of these are half to one hour lectures on a variety of topics from

### Navigation Links

#### Learning Library:

Glass Education  
for Students,  
Teachers &  
General Public

Technical  
Learning Library

#### Quick Links:

Education  
Outreach

#### Access the online library

Become a  
member

US-China Winter School  
will be here

[Local Page – TLL  
US/Japan WS](#)

## Some Details for Viewing Streaming Videos

### Several Types of Video Format

Real Media – requires Real Player (free download)

Adobe Connect – flash player – just browser

Windows (wmv) video – comes with MS operating system

All work fine from the Yuguan Hotel in Hangzhao

Please try some of our videos and let mu know  
if they work from Zhejiang University and  
if your like them.

# B. Outreach Activity for Students (Pre-College and College Students)

Low Cost, Hands-on Activities for Learning Glass Science  
with Candy Glass

A Learning Curriculum from the Kitchen Lab



International Materials Institute  
for New Functionality in Glass

# Objectives of Student Outreach Program

## Primary Goal:

To connect young students with glass & material science through hands-on learning

## Approach:

Develop series of experiments around candy glass

- material students can make and use to explore many aspects of glass science.

- low cost (most activities below \$20 (140Y) yet
- capture real glass science principles and issues
- inter-related to provide accumulated learning and prolonged engagement
- developed and tested with students
- available free to all on our website:

<http://www.lehigh.edu/imi/>



# Some Outreach Experiments to Discuss

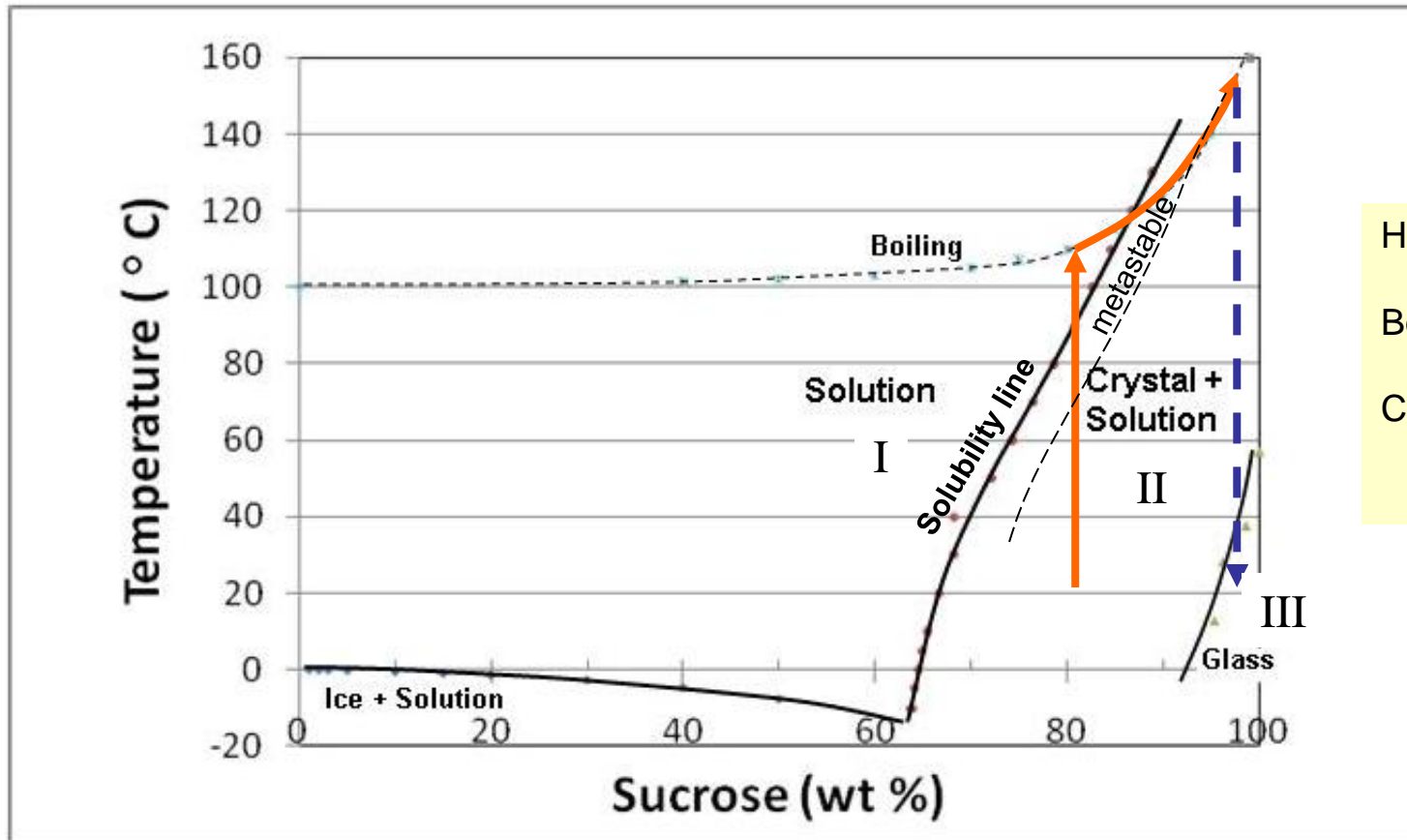
- Overview of Sugar Glass System
- Making of candy glass
- Fiber drawing experiments
- Refractive Index (2 methods)
- Crystal growth mechanisms (2)
- Thermal analysis for Glass Transition

**Many others with more detail provided on the glass learning website.  
And I would like to hear about any that you have to share.**

**<http://www.lehigh.edu/imi/>**



# Material Science – The Sucrose Water Phase Diagram

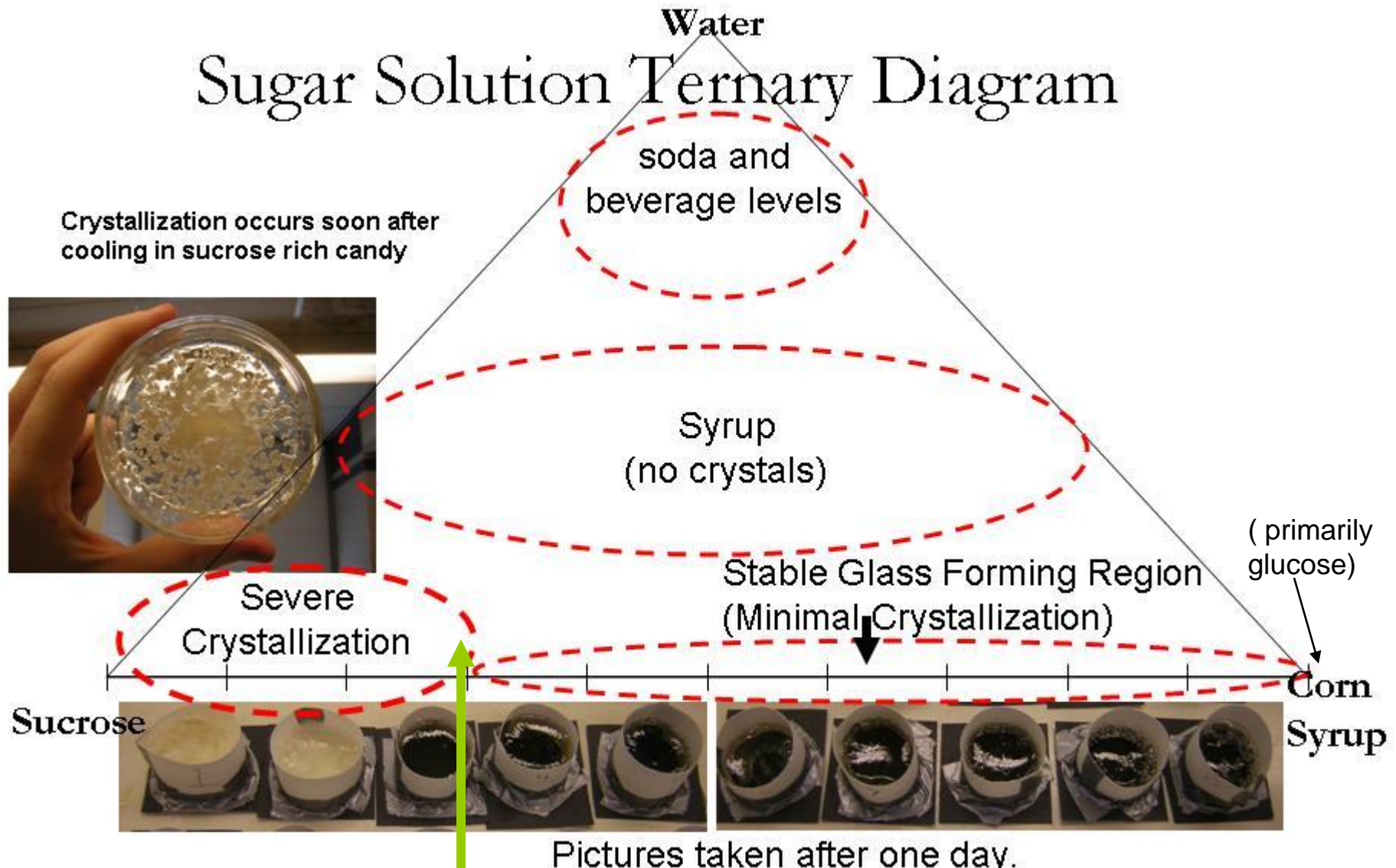


Heat to:  
Dissolve  
Boil to:  
Reduce H<sub>2</sub>O  
Cool quickly to  
Make Glass  
Avoid Xtals

Data from Mathlouthi and Reiser (ed.), *Sucrose Properties and Applications* (1995).

Problem with Sucrose: **Very prone to crystallization at low water**

# Sugar Solution Ternary Diagram



**Recommend:**

**2:1 sucrose to corn syrup (by wt.)  
for good glass with some crystal tendency**

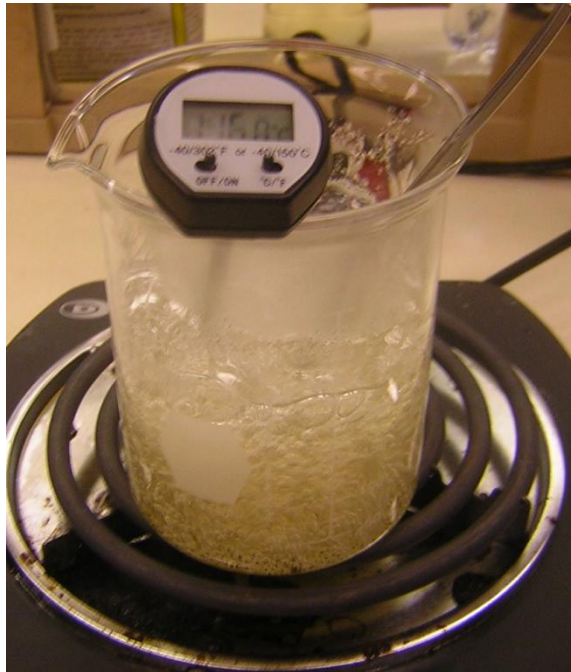
# The Making of Hard Candy (Glass) – Material Synthesis

## Phenomenological approach

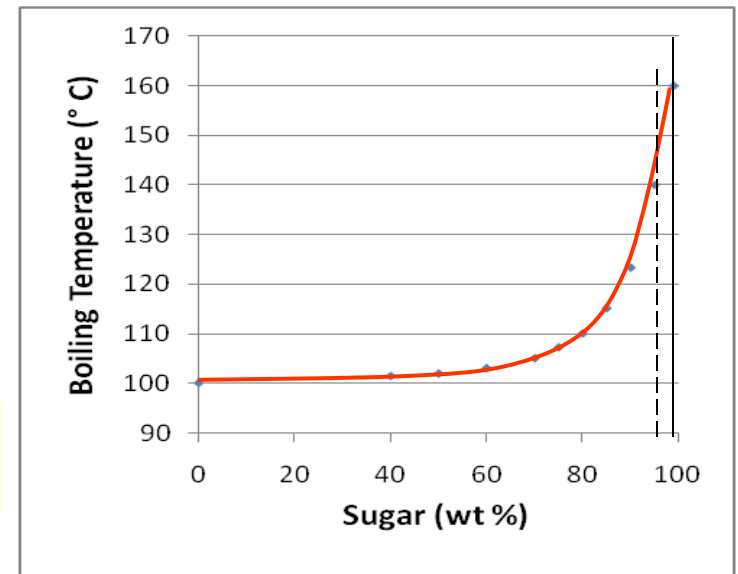
Sucrose, Corn Syrup and Water are combined and cooked-

- first to dissolve into a single liquid phase &
- then to remove most of the water.

Boiling temp provides measure of the water content.  
Boil to ~ 150 °C.



**Cost ~ \$5** in materials  
for many batches



Data from Food Industries Manual, 24th ed, (1997).

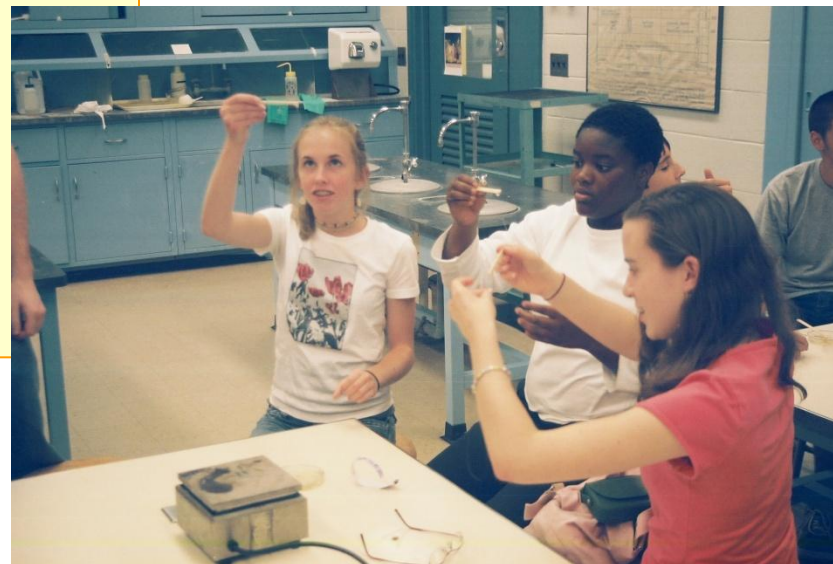


# A Favorite for the Science Camp

## Typical Science Camp Activity or Teacher Workshop

examples, properties and structure of glass  
applications e.g. optics and fiber optics  
making of candy glass  
fiber drawing

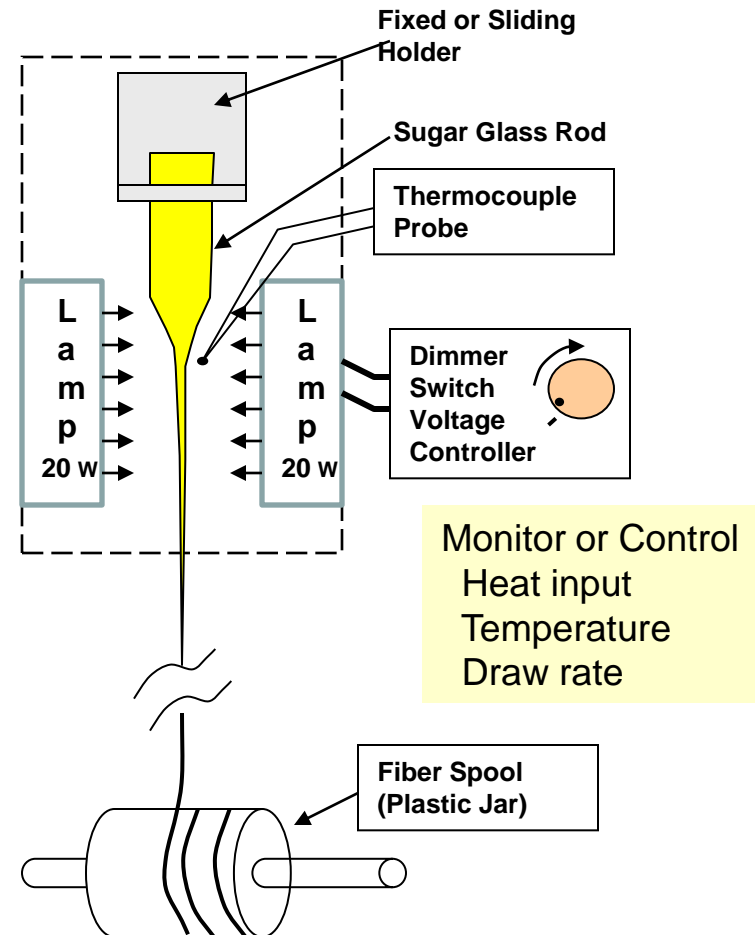
Fiber drawing never fails to excite and captivate – both young and old!



**Multiple camps and workshops have provided a wonderful testing ground for what works!**

# Fiber Drawing Tower

Mimics the optical fiber manufacture process




**Opportunity to explore –  
glass melting, visco-elasticity, heat transfer by radiation, and much more**

Estimated cost - \$20 for Tower and lamps, \$10 for dimmer switch control

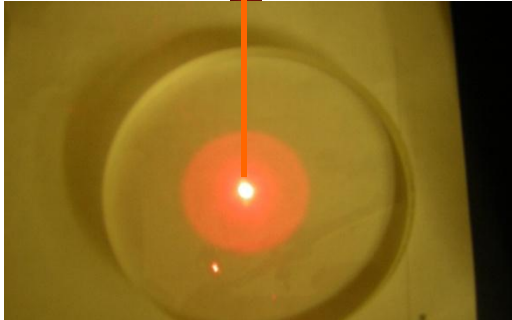
# Refractive Index – 2 Methods

## Pfund's Method



A diagram showing a laser beam passing through a cylindrical lens and hitting a surface, creating a circular spot. The beam is labeled with 'd' and 'h'.

$$n = \frac{\sqrt{d^2 + 16h^2}}{d}$$



### Requires:

- Slab of candy glass ~ 1 cm thick
- laser pointer (\$5.00)
- caliper (\$10.00)
- ring stand and clamp to hold laser

Accuracy: **std dev ~ 0.015 (~1%)**  
sufficient for index increase with boiling

## Min. Deviation Method with Student Spectrometer



sugar glass prisms in microscope slide molds

### Requires:

Student spectrometer (from school lab)  
box of microscope slides (\$20)  
and epoxy (\$3).

Accuracy:  **$\sigma \sim 0.0015$  (0.1%)**

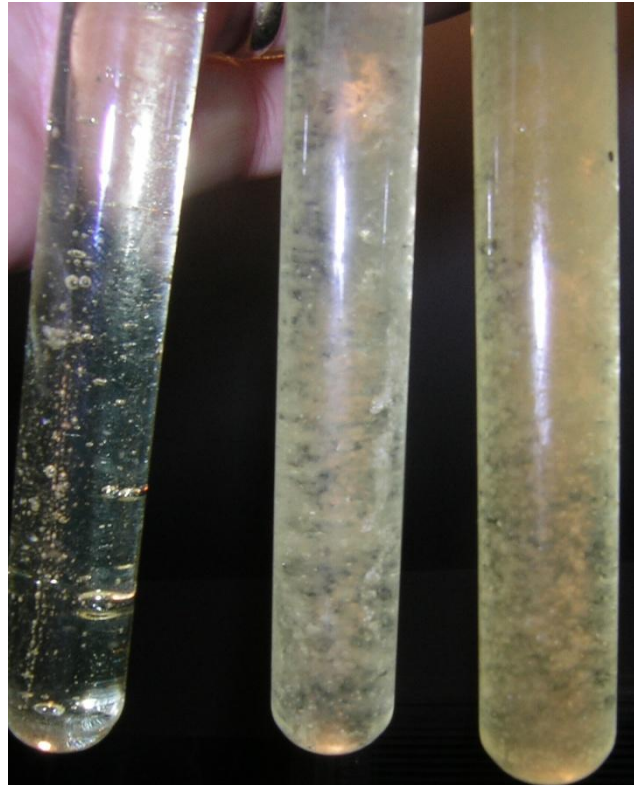


# Excellent for Crystal Growth Studies

Two Distinct Mechanisms

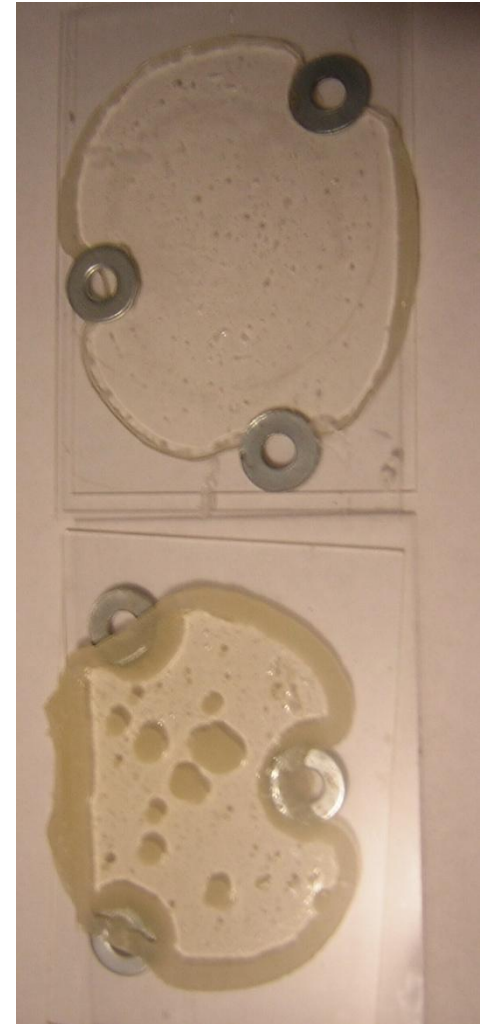


**Surface Crystal Growth**  
At room temperature  
with moisture (humidity)



**Interior Crystal Growth**  
From melt at elevated  
temperatures

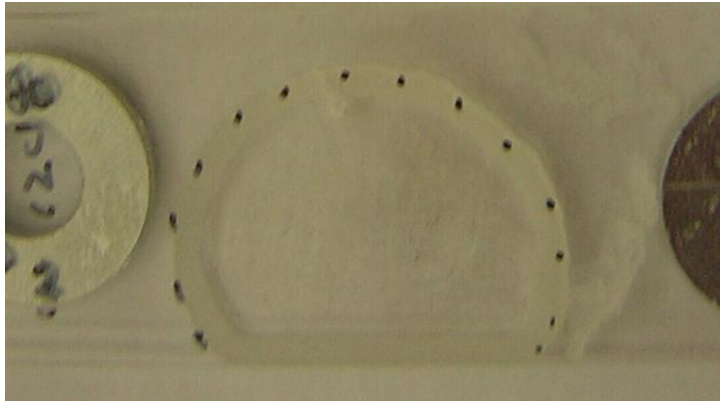
Have quantitative experiments for both



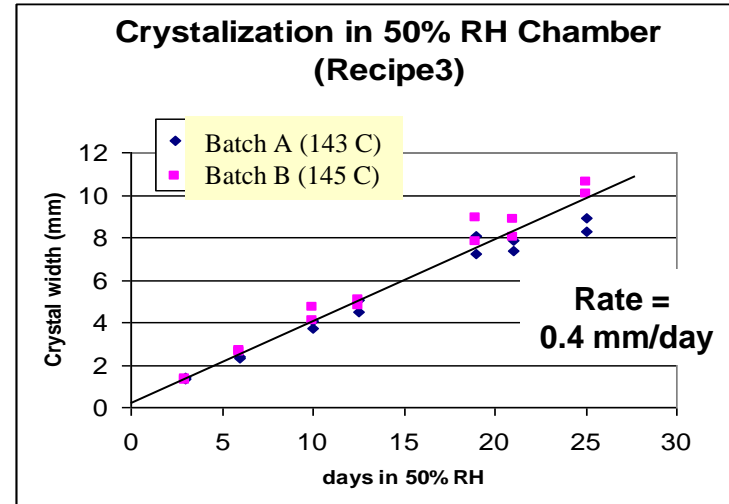
microscope slides provide  
convenient observation

# Quantitative Crystal Growth Experiments

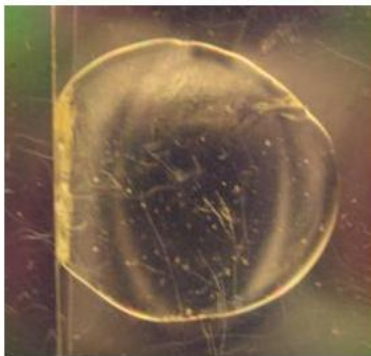
## A. Moisture mediated surface crystallization at Room Temp



Growth of outer ring after 6 days at 50% RH



## B. Finding the maximum crystal growth temperature in molten solutions

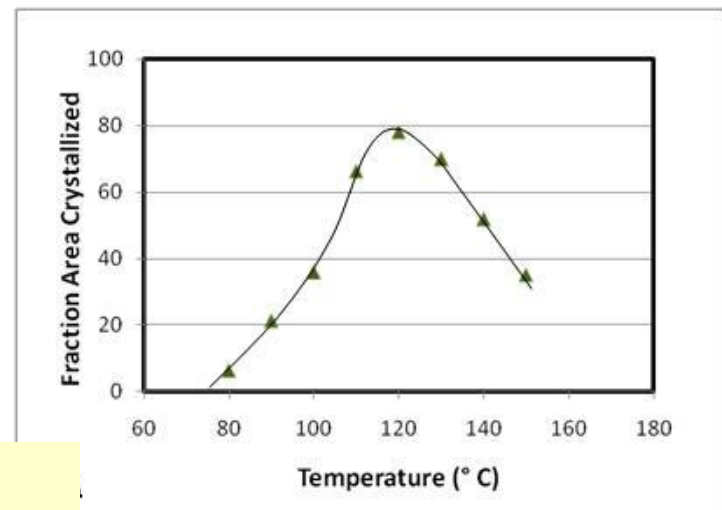


before anneal



after one hour at 100 C

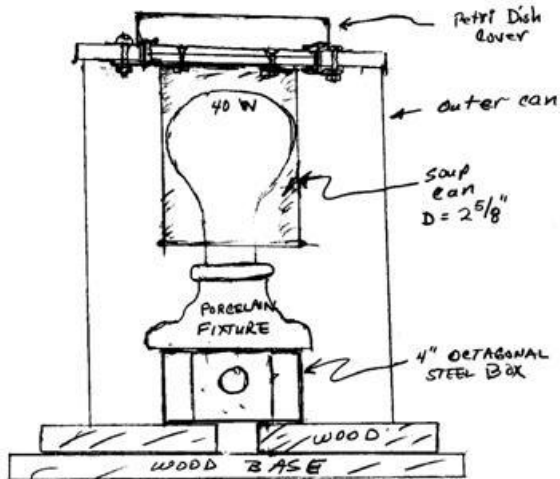
Heated in student-built oven (cost ~ \$20)



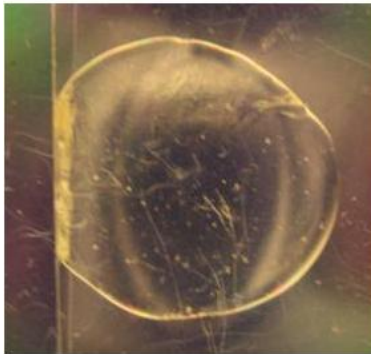


# Devitrification in Molten Solutions

## Finding the maximum crystal growth temperature



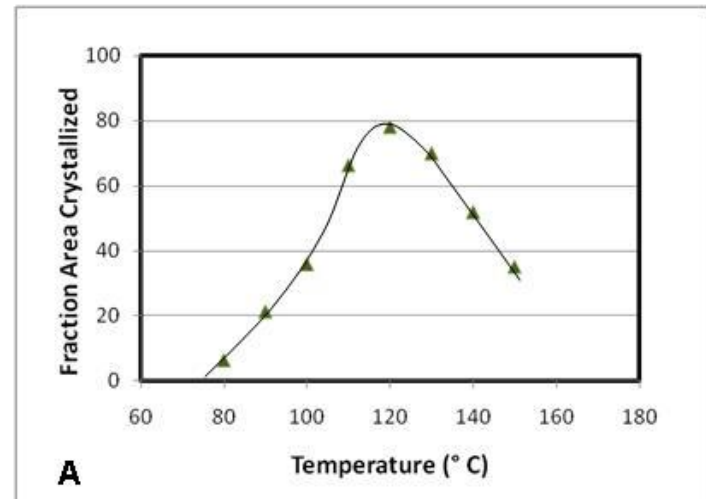
T uniformity  
 $\pm 1^\circ\text{C}$  typical



before anneal

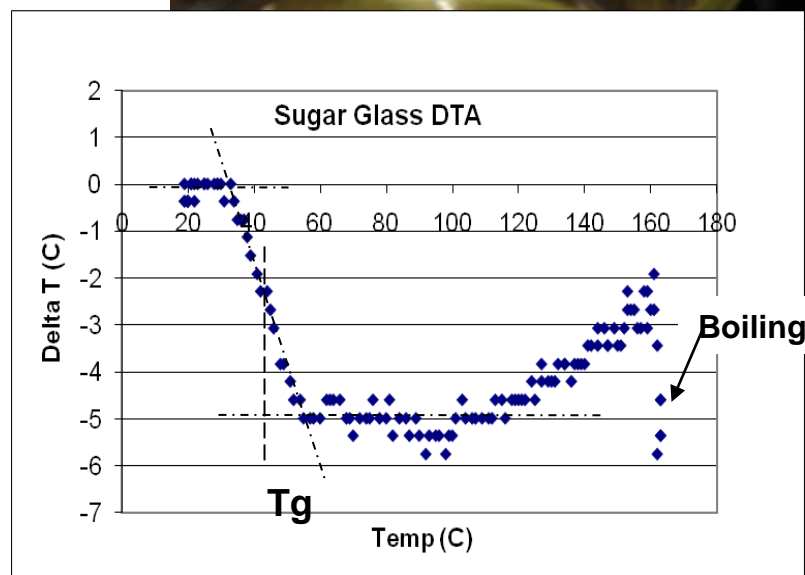
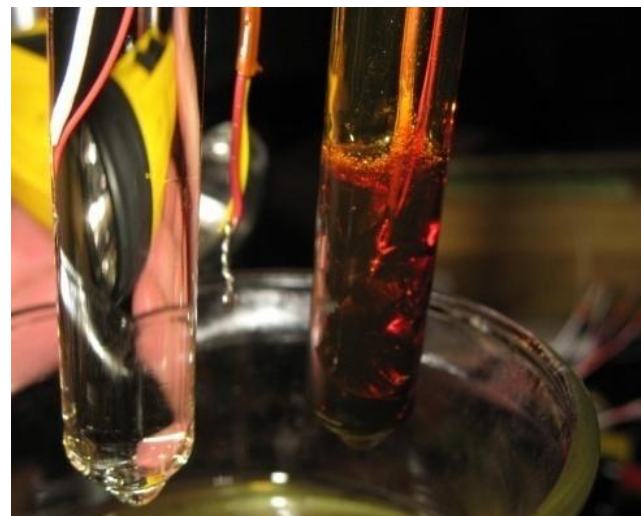
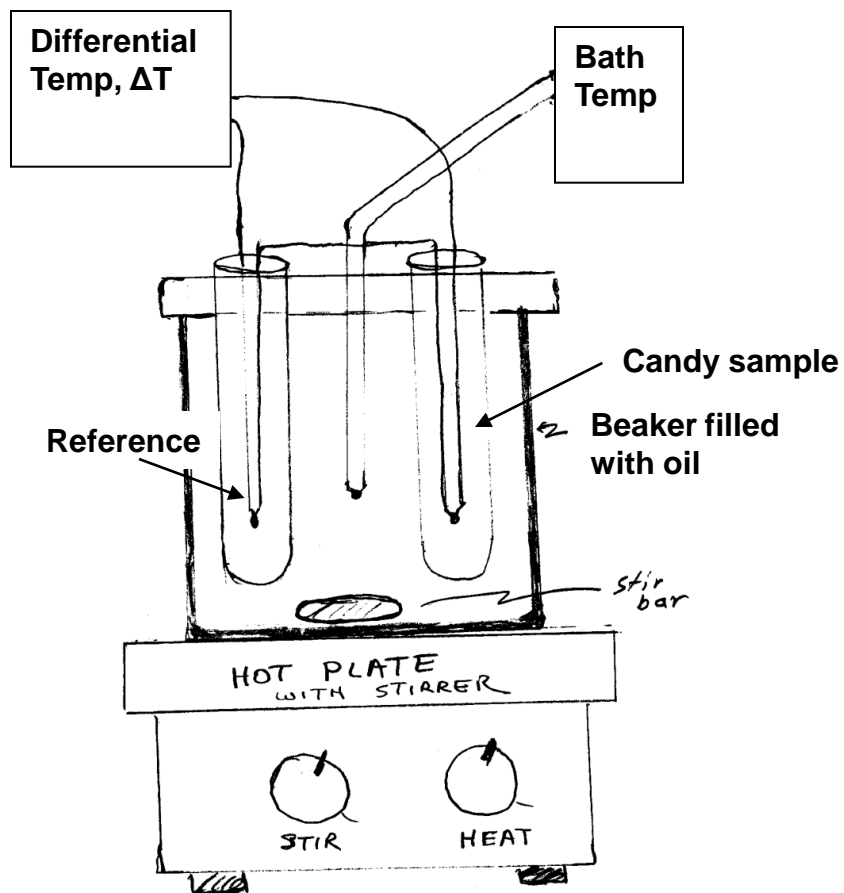


after one hour at 100 C



Oven cost ~ \$20 with temp probe Student used Image J freeware and calculate crystal area.  
 From NIH at: <http://rsbweb.nih.gov/ij/>

# Thermal Analysis (DTA) for the Glass Transition



Quantitative  $T_g$  and Melting Expts

Enabling many interesting experiments on effect of thermal history and composition .

# Summary

- **Collection of Hands-On Learning Activities in Glass Science  
(middle school through college)**
- **Inter-related around candy glass**
  - materials synthesis**
  - physical property measurements**
  - crystal growth – both surface and from melts**
  - thermal analysis and  $T_g$**
- **Website accessible for wide distribution**
- **Regular updates**
- **Consider Candy glass in your undergraduate materials lab  
and share your experience and thoughts with us**

**<http://www.lehigh.edu/imi/>**

# Acknowledgements:

## **High school students** (science projects):

Jung Hyun (Gloria) Noh (2007, 2008)

Isha Jain (2001)

## **REU students:**

Tara Schneider (2006),

Sean Kelly (2007) and

Sarah Horst (2009).

NSF for funding through the International Materials Institute for New Functionality in Glass (IMI-NFG): DMR-0409588 and DMR-0844014.

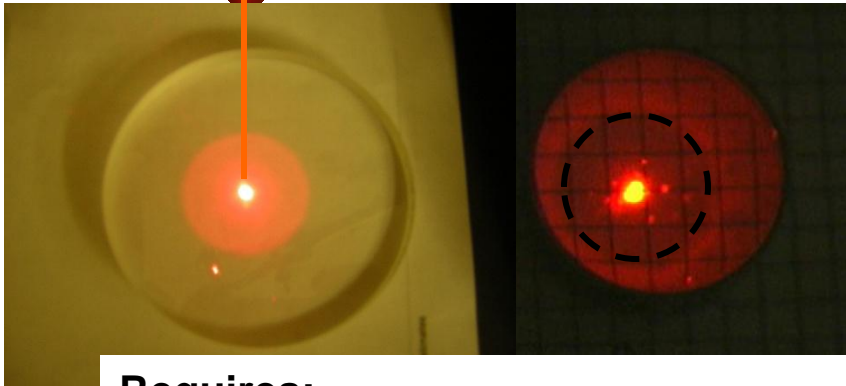
[\*\*http://www.lehigh.edu/imi/\*\*](http://www.lehigh.edu/imi/)



# Refractive Index of Candy Glass via Pfund's Method

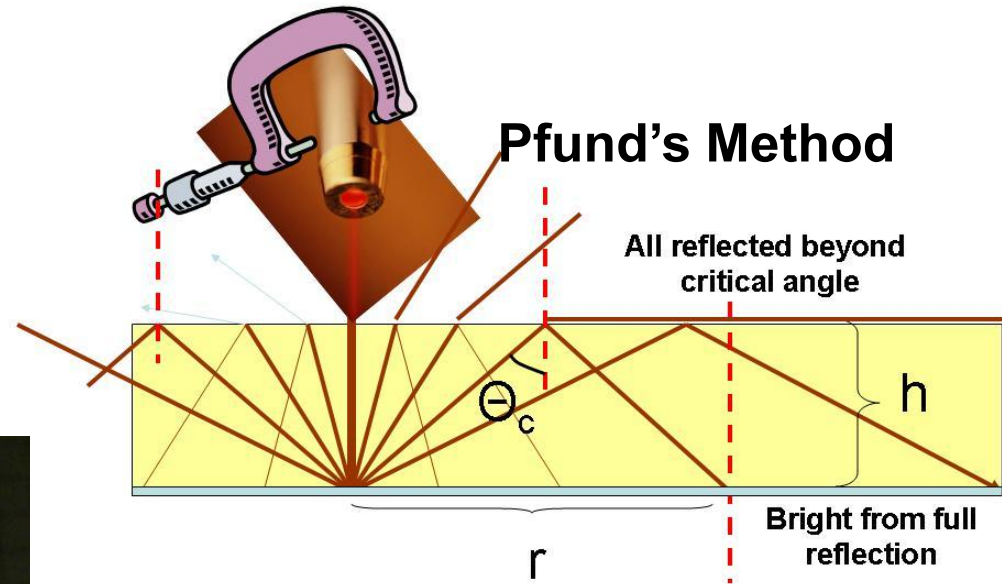


$$n = \frac{\sqrt{d^2 + 16h^2}}{d}$$



## Requires:

- Slab of candy glass ~ 1 cm thick
- laser pointer (\$5.00)
- metric ruler or caliper (\$10.00)
- ring stand and clamp to hold laser

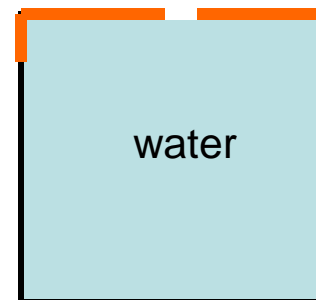


Tara Schneider, REU(2005)

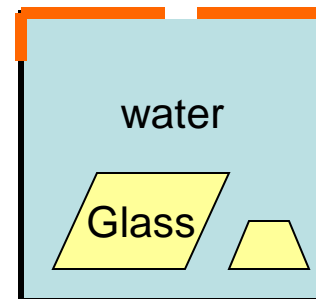
With practice Tara was able to achieve a **std dev of ~ 0.015 (~1%)**, sufficient to see the index increase with boiling temperature.



# Student-built Pycnometer for Density Determination



fixed volume



$$\text{Specific Gravity} = (\text{wt of glass}) / (\text{wt of displaced water}) \\ = (\text{wt of glass}) / \{(\text{wt of glass}) - (\text{wt of water displaced})\} ,$$

**Utilizes Centigram Balance** – available in most high school labs and salsa jar with hole in lid - **no other costs**

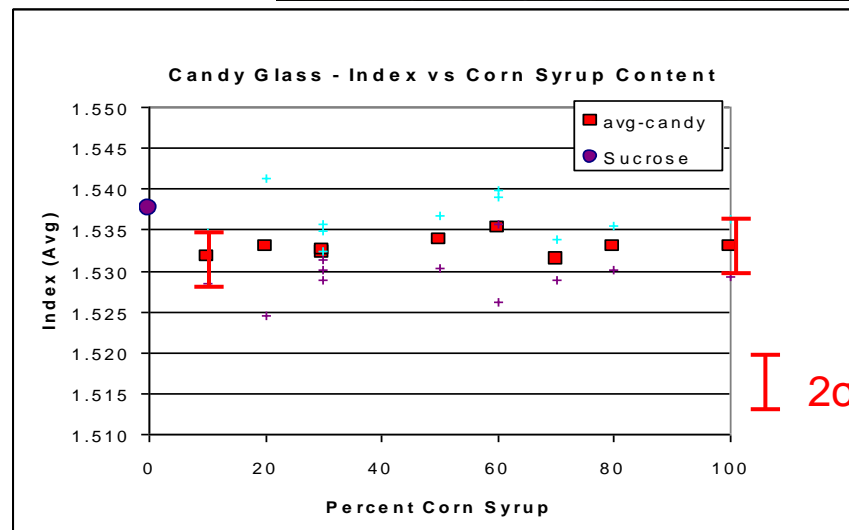
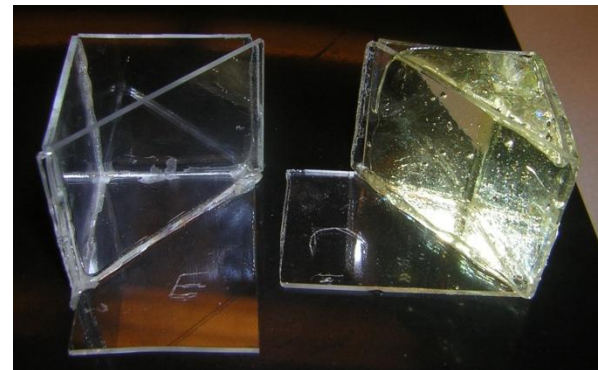
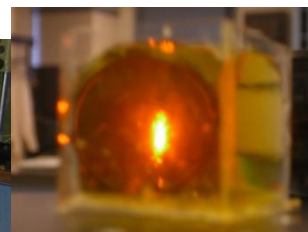
**Results for insoluble oxide glass as test sample** –  
avg. specific gravity of 1.674 with std. dev. = 0.0032 (0.2% )

# Student Spectrometer for more accurate Refractive Index Using the Min. Deviation Method



REU student Sean Kelley (2006) develops method for making sugar glass prisms from microscope slide molds and determining index of refraction to four place precision.

Having spectrometer, **cost is** a box of microscope slides (\$20) and epoxy (\$3).



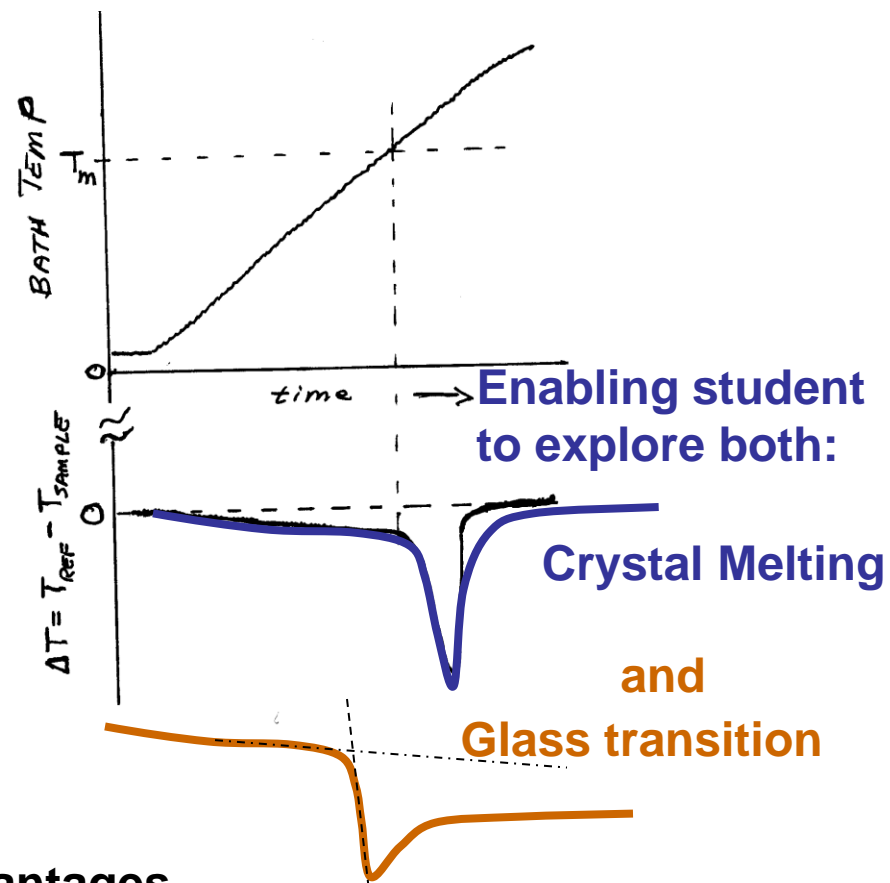
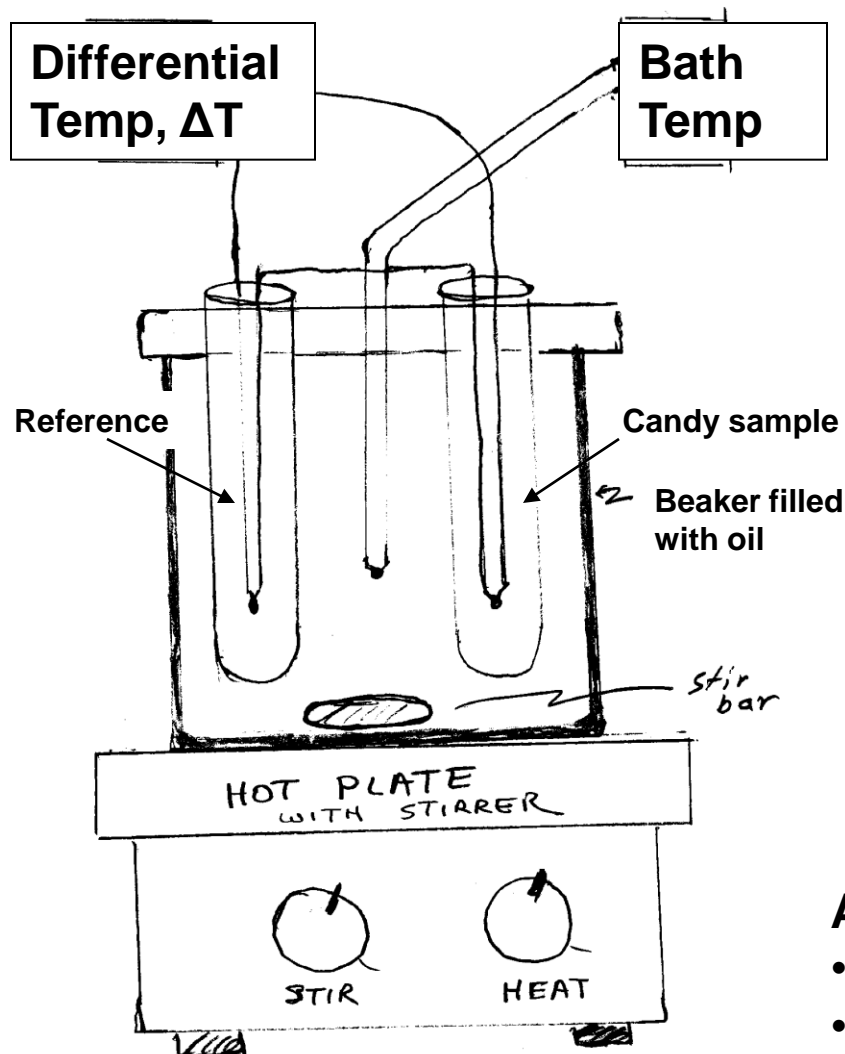
index method provides  $\sigma \sim 0.0015$  (0.1%)

**No significant dependence of index on sucrose/ corn syrup ratio.**



# Thermal Analysis for the Home Experimenter

## Getting a handle on Glass Transition



### Advantages

- Low Cost
- Student Assembled
- Can see (and poke) what's happening